Exercise and Motivational Music Improves Memory in Lectures

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Abstract

Studies examining structured recall tasks have typically had participants perform them under cardiovascular conditions. Previous studies have not considered how lecture-heavy courses' intermittent breaks are undertaken. The aim of this study was to examine whether acute, aerobic and motor exercise facilitates short-term and working memory in collegiate students. With regard to current literature, it was predicted that acute, cardiovascular exercise – similar to motor exercise – would enhance collegiate-level student's short-term and working memory. Four collegiate-level courses consisting of eighty-six participants (n = 86) were tested using the Digit Memory Test both at rest and during acute, aerobic and motor exercise. Physical exercise of body weight squats for 60 seconds with a rep range of 20-25 were implemented. The results illustrated differences; however, these differences were of no significance. Our findings do not align with prior research and the lack of relation is likely due to the exercise protocols being different in type and length. The lack of inter- and intragroup differences was intriguing as these findings suggest that long-term exercise is required to facilitate an increase in recall rather than short-term muscular endurance-based exercises. Future work is needed to further examine the impact of long-term music and exercise exposure on recall as separate stimuli.

Introduction

The notion that exercise enhances cognitive processes – otherwise considered one's mental procedures while undertaking a task – is especially promising in the work and school environment. In fact, Shu-Shih, Chin-Lung, Tsung-Min, & Yu-Kai (2016) found that exercise enhances one's attentional control – otherwise considered one's ability to maintain and manage their attentiveness. Therefore, one could assume administrators in the work and school force would discernibly suggest exercise to enhance one's cognitive processes. Unfortunately, despite research findings, exercise in the work and school setting is not practiced often. Further, with technological advances, individuals are becoming less focused with a subsequent decline in cognitive processes – specifically attention (Galvan, Vessal, & Golley, 2013). With decreasing attention spans and memory capacity, one can assume work-rate consequently declines. However, the evidence presented in this study suggest aspects of cognitive processing improves simultaneously with exercise.

Although many studies have suggested that long-term exercise benefits cognitive processes (Shu-Shih, et al., 2016; Galvan, Vessal, & Golley, 2013; Cooper-Kahn and Dietzel, n.d.), no studies have examined the effects of acute aerobic exercise on short-term memory. Further, there have been no reports on the examination of acute bursts of aerobic and motor exercise on short-term memory on collegiate students. Therefore, the purpose of this study was to examine whether acute, aerobic, motor exercise and motivational music facilitates short-term and working memory in collegiate students. With regard to current literature, it was predicted that acute, cardiovascular exercise – similar to motor exercise – and motivational music would enhance collegiate-level student's short-term and working memory.

Literature Review

The Effects of Exercise on Short-Term Memory

Short-term memory, as defined by Coles and Tomprowski (2008), is: "the amount of information that is stored and the durability of encoded information" (p.334). Further, short-term memory is considered temporary storage of incoming information. Likewise, Cole and Tomprowski (2008) suggest that short-term memory can be lost if one does not use or practice with the information stored. Sage, Beyer, Laylor, Liang, Roy, and McIlroy (2016) explored exercise and memory and further define exercises as: “increased central nervous system arousal driven by up-regulation of catecholamines, including epinephrine and dopamine” (p.93).

Sage et al. (2016) explored short-term learning post-voluntary exercise within a timed response. In this research, there were two randomly conducted sessions. There were two types of exercise intensities - one very light and the other moderate. The exercise included 25-minutes of moderate-intensity cycling of which the participants reached 70% of their maximum heart rate (HR). The lower intensity protocol had the participants cycle comfortably to ensure their HR did not increase. Once the participants finished the 25-minute cycle, they were given a shape letter task to learn. Each shape was matched with a specific letter and the shapes consisted of squares, triangles and circles. After 2-minutes, the participants were tested to see if they can recall the shapes. To ensure randomization, Sage et al. (2016) randomized the shapes to eliminate potential effects of long-term memory. Sage et al. (2016) found that participants achieved higher short-term performance post-exercise. To conclude, a single bout of moderate and low intensity, aerobic exercise can impact the rate of acquisition and recollection in healthy individuals across different tasks. There was almost a double increase in difference in the moderate compared to the low intensity exercises. The findings presented by Sage et al. (2016) can support our study and future studies as they have provided information about exercise and response time. Likewise, the findings support our hypothesis as there is a correlation between short-term memory and exercise.

Etnier, Wideman, Labban, Piepmeier, Pendleton, Dvorak, and Becofsky (2016) explored past research and the dose-response relationship relative to intensive exercise and memory. Likewise, Etnier et al. (2016) explored how this relationship differentiated by examining if the effects are evident for short-term memory. Among the many trials, numerous aspects were measured. In trial 1, short-term memory was explored. In trials 2-5, learning was measured. Twenty-four hours following trials 2-5, long-term memory was measured. Etnier et al. (2016) used the Rey Auditory Verbal Learning Test (RAVLT) to measure short-term and long-term memory, and assess learning. Etnier et al. (2016) used a standard treadmill of which the participates ran a certain distance. The distance varied from person to person depending on their fitness level. The participants a mask measuring maximal oxygen uptake (VO2 Max). The fitness test started at 3.54 kilometers per hour (kph) and increased by 0.64 kph every 2 minutes. Etnier et al. (2016) found that there was no significant difference in trial 1 due to the maximal exercise intensity used. Overall there was no significant difference in short-term memory as a function of condition and the intensities of the exercise did not effect how many words participates were able to recall the word list. Etnier et al. (2016) suggest further research should explore how exercise intensity affects cognitive performance. The authors would like to see their secondary purpose to be further researched to find ways to assess the relationships between short-term memory, learning and long-term memory and how they might differ. This study contributes positively to our study as we can explore the effects of short-term exercise on short-term memory opposed to longer bouts of exercise.

The Effects of Exercise on Working Memory

Working memory (WM) has seemingly endless real-world implications (Schwarb, Nail, & Schumacher, 2014). Oberauer defines WM as: “the system that holds, organizes and manipulates the contents of our current thoughts” (2017, p. 339). Further, WM is considered the instrument of thoughtful cognition and mental processes occurring in the brain (Oberauer, 2017). Likewise, WM is a large factor contributing to one’s success relative to complex situations such as comprehension, reasoning, problem solving, memory, and learning complex skills (Oberauer, 2017). However, Sibley and Beilock (2007) suggest working memory has individual differences. Therefore, as suggested, one's working memory and ability to process such tasks will differ relative to one's peers, colleagues, or cohort (Sibley & Beilock, 2007).

Koutsandreou, Wegner, Niemann, and Budde (2016) explored the impact both motor exercise and cardiovascular exercise had on children's working memory. Koutsandreou et al. (2016) randomly assigned their participants to a motor exercise group (including exercises such as somersaults and jumping), cardiovascular exercise group, and a control group. The researchers protocol engaged their participants for a 10-week intervention period with training occurring 3 times per week for forty-five minutes. Before and after the intervention period, the participants completed the Digit Span Letter Task to assess their short-term and working memory. Koutsandreou et al. (2016) found that working memory increased for both the cardiovascular and motor exercise program; however, the motor exercise program exhibited further benefits. Likewise, the researchers found that the control group demonstrated no increase in working memory (Koutsandreou et al., 2016). For future studies, the researchers suggest further researchers explore the neurobiological explanation relative to an exercise and cognition link (Koutsandreou et al., 2016). With reference to our study, using both a motor and cardiovascular exercise program may reap further benefits in cognition and working memory relative to the collegiate environment.

Executive functioning – measured by working memory capacity – was explored by Sibley and Beilock (2007). Sibley and Beilock (2007) aimed to investigate whether working memory capacity can increase from an acute bout of exercise. The researchers explored their hypothesis on undergraduate college students by first completing baseline measures to assess one's working memory capacity. Following the baseline measures, the participants were invited to engage in 30-minutes of self-paced exercise. The exercise sessions were conducted 1 week apart. Following each session, the participants completed the Operation Span Task. The Operation Span Task is a test of which one attempts to remember a list of words while completing mathematical equations (Sibley and Beilock, 2007). Along with the Operation Span Task, the participants completed the Reading Span test by reciting and writing words and sentences (Sibley and Beilock, 2007). Sibley and Beilock (2007) found that those who exhibited lower scores in their executive functioning benefitted further from the exercise than their counterparts who exhibited higher executive functioning scores. With reference to our study, randomizing trials as Sibley and Beilock demonstrated may prove beneficial as randomization can remove potential biases.

The effects of acute, moderate intensity resistance exercise on working memory was explored by Hsieh, Chang, Hung, and Fang (2016). Hsieh et al. (2016) used a two-study approach by examining a younger cohort (ages 21-30) and an older cohort (ages 65-72). Hsieh et al. (2016) employed a resistance training protocol including 2 sets of 10 repetitions at 70% of their participants 1-repetition maximum. For both age cohorts, after the training protocols, Hsieh et al. (2016) used the Sternberg Working Memory Paradigm as a cognitive task measuring reaction time and response accuracy relative to one’s working memory. Hsieh et al. (2016) found that both cohorts exhibited shorter reaction times relative to their working memory. For future studies, Hsieh et al. (2016) suggest adopting a holistic, inter-disciplinary approach by assessing further mechanisms that can impact cognitive performance. Hsieh et al. (2016) demonstrated that gathering information on men of various ages exhibits fair results; however, we would like to adopt this approach by measuring various sexes.

Zach and Shalom (2016) investigated the difference between sport-specific activity, sub-maximal aerobic exercise, and anaerobic a-lactic resistance exercise relative to one's working memory. The researchers conducted 3 trials. The first trial consisted of a pre-intervention test. The second and third trial involved the participants performing aerobic or anaerobic a-lactic exercise. The exercise protocols consisted of exercises such as running for 15-minutes or body weight resistance exercises. Zach and Shalom (2016) used an adapted Digit Span Test using the forwards measure only and the Visual Memory Span Test after all of the exercise protocols. Zach and Shalom (2016) found that sport-specific activity improved working memory further than physical activity in general. Zach and Shalom (2016) suggest that future researchers examine longer intervention periods with a larger range of participants (N=>20). Despite the excellent findings sport-specificity exhibited, this approach may not be feasible in a classroom setting. First, not all participants will display an athletic background. Likewise, conducting a sport-specific protocol per participant can be time-consuming.

The Effects of Acute Cardiovascular Exercise and Executive Control Function

Acute cardiovascular exercise effects on cognitive function were examined using an executive control task. (Hillman, Jerome, & Snook, 2003). The executive control task compared neuroelectric and behavioral performance at baseline with post-exercise in undergraduate students (Hillman et al., 2003). Hillman et al. (2003) suggest that exercise increases the efficiency of effortful cognitive processes, despite the fact that it may not influence overall intellectual functioning. Further, exercise is not necessarily beneficial for automatic processes or tasks that are assumed to be easy. An easy task includes anything that doesn't require much consciousness. Rather, exercise is beneficial for cognitive processing when dealing with complex tasks that require conscious thought and executive functioning. Cooper-Kahn and Dietzel (n.d.)

state: “executive functions are a set of processes that all have to do with managing oneself and one's resources in order to achieve a goal. It is an umbrella term for the neurologically-based skills involving mental control and self-regulation” (p.3). Further, executive functions is a measure of all mental processes occuring in order to achieve one’s motive.

Stimulus evaluation tasks have long been employed to study executive control using methods that force participants to make a decision and/or execute a response. For example, the Eriksen Flankers Task (Eriksen and Eriksen, 1974) - which is used by Hillman et al. (2003) - requires participants to differentiate between two letters that are flanked by an array of other letters. These letters have different action schemas associated with them. Incompatible and neutral conditions of the Eriksen Flankers Task (Eriksen and Eriksen, 1974) requires participants to respond as quickly as possible to a centrally presented target letter. When ‘F’ was the target stimulus, participants responded with their left index finger. When ‘X’ was the target stimulus, a right index finger response was required. The incompatible condition had the target response flanked by the opposing target stimulus (i.e. FXF or XFX). The neutral target response was flanked by letters with no response assignment (e.g. LFL, LXL). This incompatible condition requires greater amounts of executive control since incongruent arrays result in response delay due to activation of the incorrect response.

Hillman et al. (2003) recruited moderately active participants who partook in a baseline session. Following the baseline session, the participants underwent another session of which they were subject to a graded exercise stress test. The exercise session began with a 30-minute bout of self-paced treadmill exercise, followed by completion of the Flankers Task after participants’ heart rate (HR) returned within 10% of baseline (pre exercise levels). Mean HR for this studied was 162.4 beats per minute or 83.5% maximal heart rate. Participants were instructed to exercise at a pace that was somewhat hard to hard on the ratings of a perceived exertion scale.

To date, only two studies have examined the influence of an acute bout of exercise on cognitive processing using event-related potentials (ERP) - neither of which employed tasks requiring extensive amounts of executive control. A consistent picture is beginning to emerge when the current findings are considered along with the two previous neuroelectric studies (Magnie, Bermon, Martin, Madany-Lounis, Suisse, Muhammad, & Dolisi, 2000; Nakamura, Y., Nishimoto, K., Akamatu, M., Takahashi, M., Maruyama, A., (1999).) of acute exercise effects on information processing. Further, exercise was found to increase cognitive functioning - more specifically, executive control processes. Contemporary theories suggest that the amplitude of executive function reflects allocation of attention and context updating of working memory resources (Donchin and Coles, 1988), and has also been shown to be proportional to the amount of resources allocated to a particular task or stimulus (Wickens, Kramer, Vanasse, & Donchin, 1983). Therefore, the current findings imply that acute bouts of cardiovascular exercise may facilitate the allocation of attentional and memory resources - hence a benefit in executive control function.

The Effects of Exercise-Induced Arousal on Cognitive Task Performance

Much of the research on the relationship between exercise and cognition has tested predictions drawn from “arousal” theories (Lambourne & Tomporowski, 2010). Common to these theories is the assumption that cognitive performance is dependent on the allocation of energetical resources to meet task demands. This is of great significance relative to our study because acute exercise has been hypothesized to alter brain systems that influence how mental resources are dedicated to cognitive task performance.

The notion of the evaluation of exercise induced arousal has been at the center of many published studies. However, the methods used to manipulate participants’ arousal levels have not been uniform. Three different approaches have been taken to test predictions drawn from the arousal hypothesis (Lambourne & Tomporowski, 2010).

One approach has been to use experimental protocols that mimic the exercise regimens prescribed to recreational runners or cyclists. This approach has utilized steady-state cardiorespiratory exercise designed to improve mood and increase feelings of well-being. The existence of these benefits has been supported by empirical evidence, in which individuals report positive changes following moderate levels of steady-state exercise lasting at least 20-minutes. Another approach researchers have taken to examine the exercise–cognition relation has been to model experimental protocols on predictions generated from the inverted-U hypothesis. Cognitive performance was measured at multiple points during exercise that systematically altered participants' level of physiological arousal as measured by heart rate, oxygen uptake, rate of perceived exertion, or other biological indices. Cognitive performance was predicted to improve and peak as physiological arousal increased and then deteriorate as arousal levels approached maximal levels. Lastly, the third approach to examine the influence of exercise on cognition has been to focus on the fatigue producing aspects of physical activity.

Experimental protocols employed in these studies typically require participants to complete incremental-load exercise to voluntary exhaustion or to maintain a physically demanding steady-state exercise protocol for an extended period of time. In such studies, it has been predicted that participants' cognitive performance would be impaired both during and immediately following the termination of exercise.

Since the protocols of our study include squatting 30 times, the closest type of studies that we can compare our data to is that of the first approach. Depending on the approach taken, researchers have expected exercise to either facilitate or impair cognitive function. The first approach would be impractical for us since we don't have 20-minutes of time in a lecture to do steady state cardiorespiratory exercise.

A wide range of mental tasks have been employed in these studies that measure basic processes such as perceptual organization, information-processing speed, and simple- and choice-response time, to tasks that measure memory and high-level executive control processes. The different approaches taken by researchers, coupled with the wide variation in outcome measures, have made efforts to summarize and synthesize research findings difficult.

Based on the available evidence, it was concluded that acute exercise had selective effects on cognitive processing. Exercise appeared to facilitate certain aspects of processing such as response speed and accuracy and enhanced the processes involved in problem-solving and goal-oriented actions. This was particularly true when a task involved inhibition of a response - one component of executive function. In contrast, exercise appeared to have no effect on tasks that measured perceptual processing, sensory processing, or memory retrieval.

The Effects of Exercise on Long-Term Memory

Wang and Wang (2016) investigated the effects of different treadmill exercise intensities on long-term memory. Experimentations were conducted on fifty female rats that were trained by the T-maze delayed spatial alternation (DSA) task. In the DSA task, the rats were timed from when they entered the maze until they reached the food container in the maze. This task was performed with three different delays of 10 seconds, 60 seconds, and 300 seconds. Following completion, the rats then underwent 30 days of treadmill runs for 30 minutes at four different intensities of 0 m/min (control), 15 m/min (low), 20 m/min (middle), 30 m/min (high). Further testing was conducted in DSA, passive avoidance and the Morris water maze tasks. Findings indicated that treadmill exercise can improve long-term working memory and spatial memory (Wang and Wang, 2016). Wang and Wang (2016) found that low intensity exercise positively affects short-term delayed working memory while middle and high intensity exercise positively affects long-term delayed working memory. Examining the effect of exercise intensity on working memory was recommended for future aims in research. However, this study is not relative to our study because we are trying to determine if exercise induces enhanced, short-term recall on undergraduate students.

McNerney and Radvansky (2015) explored the influence of exercise on memory using three different types of memory tasks. The first task was the serial order task, which measured implicit, procedural memory. The second task was the paired-associate memory task, which focused more on explicit forms of memory. Finally, the third task was the sentence memory task that assessed more complex forms of memory. The participants in this study completed two experiments with relatively similar procedures. Experiment 1 looked at the influence of exercise on memory tasks such as learning and memory testing. Experiment 2 involved people encoding the material prior to exercise. The similar study design was used in order to see if the researchers could replicate the results. Before completing the tests, the participants played a 30-minute game of Sudoku. The results of this study demonstrated that exercise can improve both procedural and sentence memory. Findings in this study suggest that exercise does boost memory consolidation over no exercise. McNerney and Radvansky (2015) suggest that, in future studies, researchers make the control group to undergo a guided relaxation period rather than a cognitive demanding task.

The Effects of Anaerobic Exercise and Memory

Babaei, Damirichi, Mehdipoor, and Tehrani (2014) designed an experiment to evaluate basal brain-derived neurotrophic factor (BDNF) levels relative to memory performance. BDNF is mostly produced by the central nervous system and a range of peripheral tissues. It is a factor that encourages synaptic plasticity. Babaie et al. (2014) also evaluated the responsiveness of the BDNF regulation system to acute aerobic and anaerobic training in athletes and sedentary groups. In experiment 1, the goal was to evaluate basal serum BDNF level, platelets and memory performance. In experiment 2, the basal serum BDNF, platelets and memory performance were measured again, with the addition of a single bout of aerobic or anaerobic exercise, to compare the changes. The findings showed that there was a low basal serum BDNF level with better picture recall memory in active individuals than sedentary. Platelet numbers were increased with the bout of aerobic and anaerobic exercises, which helped elevate levels of BDNF serum. Anaerobic exercise caused more elevation in platelets. In future studies, Babaei et al. suggest measuring the central nervous system and peripheral BDNF changes in athletic and sedentary individuals.

Methods

Participants. Four collegiate-level classes were thoughtfully selected from an institution in New Westminster, Canada (n = 86). The classes were randomly assigned to one of two experimental groups – a control group and an exercise group. The participants all provided consent before inclusion in the study. The study was approved by Douglas College's Research Ethics Board. Further inclusion criteria included no exercise-inhibiting injuries – specifically in the ankle, knee, and hip flexors (i.e. ACL tears, ankle sprains, etc.). Likewise, participants were excluded due to an absence on one or two of the testing days.

Digit Span Test. The Digit Span Test was applied to measure the student's short-term and working memory. The Digit Span Test shared about 25-40% total variance with the standardized measure of the Digit Span recall and a reliability of 0.79 (de Paula, Malloy-Diniz, & Romano-Silva, 2016). The test includes a *Digits Forward* section – including 8 trials – and a *Digits Backwards* section – also including 8 trials. The first trial of both digits forward and digits backward requires little cognitive processes. As the Digit Span Test progresses, the trials simultaneously advance requiring further cognitive processing. However, the digits backwards protocol is seemingly the most cognitively taxing task. The trials are verbally stated followed by the subjects recording the numbers on the adapted examination sheet provided (Kang, Jecanski, Chohan, & Badyal, 2018). The order of the numbers recited is accounted for; therefore, the Digit Span Test measures whether or not one can recall the numbers in the correct sequence too.

Procedures. Prior to the 10-minute break, we conducted the task. The control group was given no exercise. They were instructed to stay seated as we distributed the adapted Digit Span Test's submission sheet. We verbally stated the numbers and the class had to sit and listen. The subjects were instructed to begin writing the numbers recalled once the test administrator read the last number aloud. After 10 more seconds, the next trial's numbers were read aloud.

The experimental group was given an exercise protocol to adhere to prior to the test. The participants were instructed to perform body-weight squats for 60-seconds to stimulate a short-term, aerobic exercise – more specifically, the squats simulated a muscular endurance protocol (Nunley, n.d.) as one will always be using both their aerobic and anaerobic systems respectfully during this time period. This muscular endurance protocol encompasses the realms of motor exercise (body-weight squats) and short-term, aerobic exercise (60-second protocol). The participants were given an aim of 20-25 body-weight squats within the 60-seconds. Along with the body weight squats, the participants were exposed to motivational music simultaneously. Following the 60-seconds of squats, the participants were taken through the Digit Span Test just as the control group was. Following the protocols (control and experimental), all students were dismissed at the same time for their break.

After the first session with each group, we gave the control group the opportunity to perform the Digit Span Test with the exercise protocol – and vice versa. However, each session was separated by a few weeks to remove any immediate re-test implications. Likewise, we executed our protocol prior to the 10-minute break to remove any potential biases and any unaccounted factors that could potentially skew our data.

Results

A single-factor ANOVA conducted on forwards scores and backwards scores revealed differences between the control groups (FBC) and exercise groups (FBE). The data exemplified how exercise supplemented with motivational music does increase short-term and working memory; however, these differences were not significant (FBC = 19.06, FBE = 19.88). A single-factor ANOVA conducted on just forwards scores revealed there was a difference as exercise and music did simulate recall; however, this difference was not significant. An ANOVA revealed a significant effect for backwards scores in one of the classes ($P < 0.04$). The difference in the backwards scores exemplified how exercise supplemented with motivational music did enhance recall; however, the findings were inconsistent because only one out of the four classes revealed a significant effect (Overall $P < 0.05$). Despite the protocol, recall improved from no-exercise conditions to exercise-induced conditions.

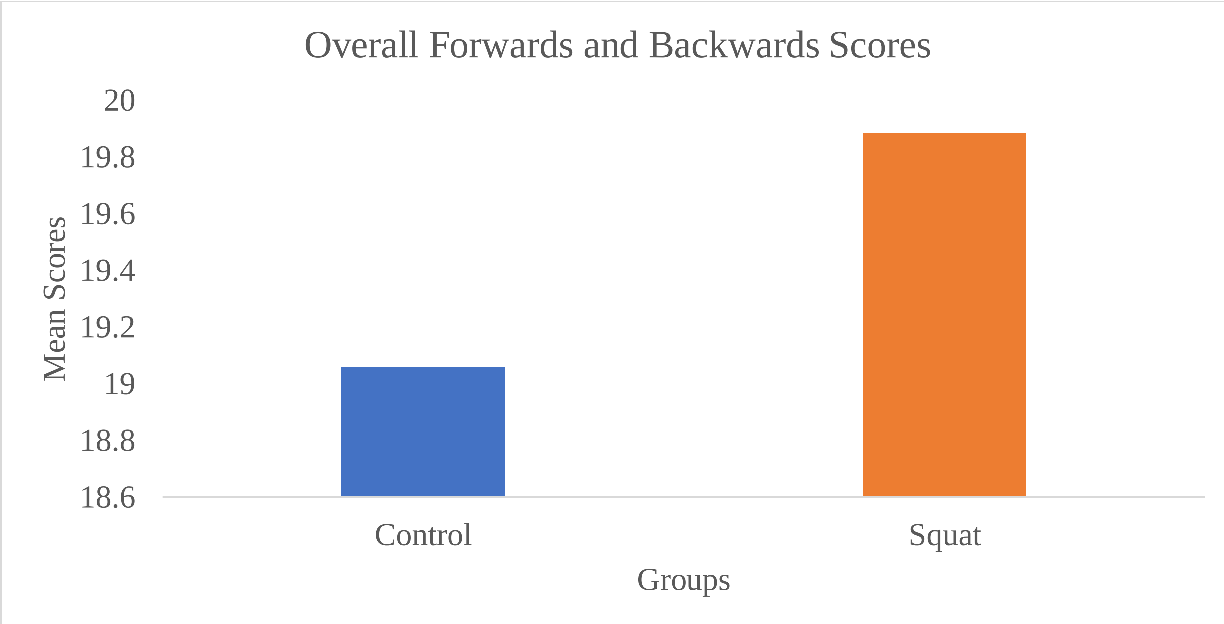

Figure 1. Combined mean number of numbers recalled in both the forwards and backwards protocols with and without exercise.

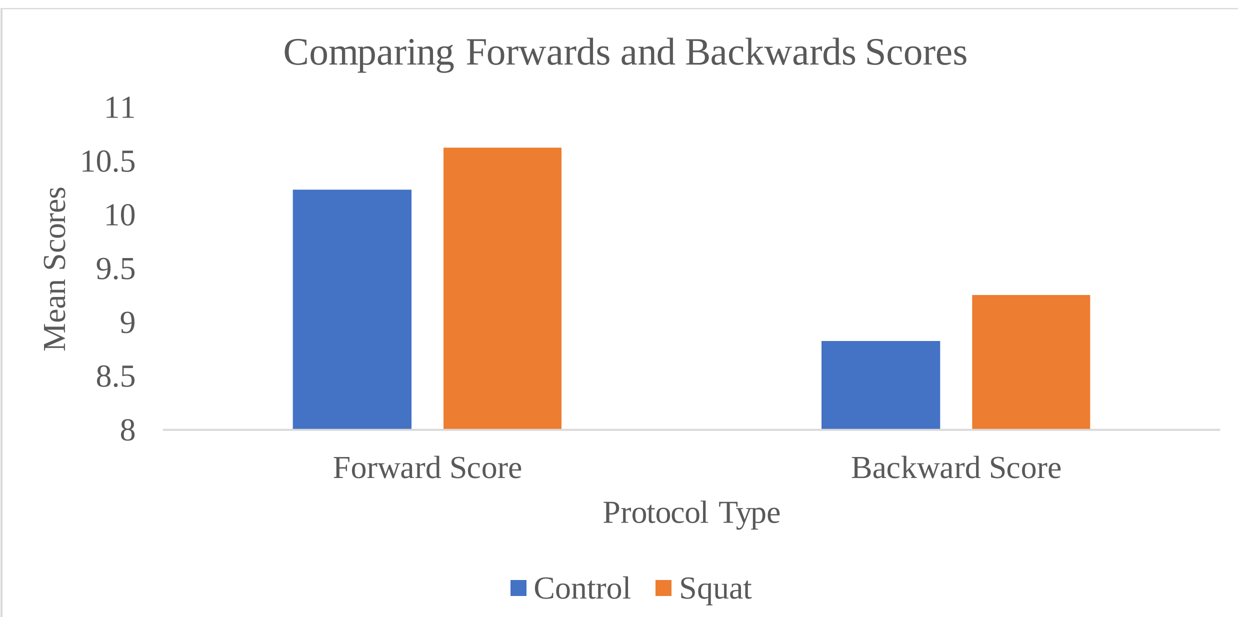

Figure 2. Mean number of numbers recalled compared between both the forwards and backwards protocols with and without exercise.

Discussion

Our participants may have exemplified differing results across classes due to their individual differences (Sibley and Beilock, 2007). Sibley and Beilock (2007) suggest one's working memory and ability to process tasks – such as the Digit Span task – will differ. That is, one will exemplify different results than their peers, colleagues, or cohort (Sibley and Beilock, 2007) perhaps due to differences such one's ability to cognitively process such tasks or one's learning style.

Hillman et al. (2003) suggest that exercise increases the efficiency of effortful cognitive processes – hence why we may have seen increased scores in the backwards protocol compared to the forwards protocol. Likewise, the suggestions posed by Hillman et al. (2003) coincide with our results for one of our classes in the backwards protocol ($P < 0.04$). To further illustrate the findings presented by Hillman et al. (2003), exercise is not necessarily beneficial for automatic processes or tasks that are assumed to be easy. Rather, exercise is beneficial for cognitive processing when dealing with complex tasks that require conscious thought and executive functioning.

The backwards (incompatible) protocol of the Digit Span Test requires greater levels of executive control. The backwards condition requires greater amounts of executive control since incongruent arrays result in response delay due to activation of the incorrect response (Eriksen and Eriksen, 1974). Having to listen to and memorize a set of numbers only to recite or record them backwards qualifies as a much more complex task than reciting them normally.

In further support of requiring complex tasks that need conscious thought and executive functioning in order to achieve benefits from acute exercise, Duncan-Johnson (1981) examined P3 (event related potential) latency in the study of Hillman et al. (2003). P3 latency was shown to reflect cognitive processing and classification speed. The results of P3 latency were only observed to be shorter for the backwards trials of the protocol. Thus, as initially suggested by Chodzko-Zajko (1991), effortful or cognitively taxing tasks may be more sensitive to the beneficial effects of exercise compared to tasks that require minimal effort. Our average backwards scores were much closer to being statistically significant than our forwards scores were; therefore, our data exemplifies exercise and motivational music may increase recall more if the task is cognitively taxing.

Vaughn & Baker (2008) stated that it is important to notice the factors that can influence the interaction between a student and a teacher – such as one's teaching style, learning style, and the interaction of both styles. Students may have problems if their preferred learning style does not relate well with the teacher's preferred teaching style. Brumpton et al. (2013) suggest that a mismatch between a preferred learning style and a preferred teaching style can lead to problems with effective educational interaction between the teacher and the student. We have to keep in mind that students may have a different preferred learning styles compared to their peers, which may not be compatible with their teacher's preferred teaching style.

According to Vaughn and Baker (2008), there are five styles of teaching – the expert, formal authority, personal model, facilitator, and the delegator. Likewise, there are six learning styles (Vaughn & Baker, 2008) – the independent learner, dependent learner, collaborative learner, avoidant learner, participant learner, and competitive learner. There are also students who have a compatible style of learning compared to their teacher's teaching style. Such students tend to have more success in processing information effectively. However, for those who have a hard time adjusting to their teacher's teaching style, they may exemplify poor ability to recall and retain course content. Gaining insight into preferred learning methods gives teachers a better understanding of how they can facilitate an enhanced level of learning (Ranganath & Josephine, 2015). Most students have multiple styles of learning, it's just a matter of teacher shaping the teachings so that the learners can understand them effectively. Therefore, our results may have illustrated differences because of one's respective teaching and learning style(s).

Given our sample size, we could expect to see more statistically significant scores if we had used varying samples. Further, we used two classes of which the course content and course instructor was the same; thus, there were two classes exposed to the same teaching style. For these reasons, we may have yielded similar results across classes due to a lack of differences among professors and course content. Likewise, with an increased sample size and larger variety, we may have seen a positive correlation between exercise and recall. The fact that two of our four subject groups came from the same class and the same instructor limits our variance to the subject's mental stimulation prior to our protocol. Also, a group of our subjects were exposed to a course typically known for learner engagement in comparison to the other courses that were tested. This may have limited their ability to achieve significant scores following our squatting protocol since their room for improvement would be smaller. Their room for improvement would be smaller because their stimulation levels prior to their control protocol were already high compared to our other group of subjects that were sitting through lecture-heavy classes with less classroom engagement.

Our data may have been influenced due to the time of data collection(s) and amount of lecture endured among classes. Considering many professors take their breaks at varying times (30+ minutes), our participants may have been exposed to extended sitting hours. That is, some of our participants were exposed to roughly 30-minutes of lecture before their break whereas other participants were exposed to an hour of lecture before the break. Therefore, our participants' ability to process such tasks – like the Digit Span task – would differ relative to their peers due to the timing of breaks.

Conclusion

In conclusion, our results failed to provide significance relative to this study. However, our results did exemplify differences and support the hypothesis that acute bouts of exercise supplemented with motivational music would enhance one's recall. However, it remains to be determined if short-term, acute bouts of exercise supplemented with motivational music influences tasks requiring greater cognitive functioning – such as tasks more cognitively taxing than the *Digits Backwards* task of the Digit Span Test. However, additional research is needed to determine if short-term, acute bouts of exercise has a direct effect on different types of learning styles. Given the results from this study, further examination is warranted using tasks that vary in difficulty to better determining the specificity of the relationship of acute exercise and cognitive processing. Likewise, incorporating different modes of assessment – such as verbal or visual – may warrant different results as this method can accommodate to the various learning styles.

Future studies should also consider the length of the exercise intervention. One-minute of squatting is significantly less than 30-minutes of aerobic exercise that typical studies regarding this subject implemented. It would be interesting to compare the effects of two-minutes of squatting compared to the results illustrated in this study from one-minute of squatting. However, as the time increases, impracticality in the classroom setting increases too. Teachers at the collegiate-level likely do not have the time to implement an exercise protocol that is more than a few minutes. Even if teachers find more time for exercising in class, factors such as decreased comfortability from sweating may become an issue with overall student-experience which can potentially decrease academic performance.

References

Babaei, P., Damirichi, A., Mehdipoor, M., & Tehrani, B. S. (2014). Long term habitual exercise is associated with lower resting level of serum BDNF. *Neuroscience Letters, 566*(1), 304-308. Doi: 10.1016/j.neulet.2014.02.011

Brumpton, K., Kitchener, S., & Sweet, L. (2013). Learning styles in vertically integrated teaching. *Clinical Teacher*, *10*(5), 282-286. doi:10.1111/tct.12024

Chodzko-Zajko, W. J. (1991). Physical Fitness, Cognitive Performance, and Aging. *Medicine & Science in Sports & Exercise, 23*(7). DOI:10.1249/00005768-199107000-00016

Coles, K., & Tomporowski, P. D. (2008). Effects of acute exercise on executive processing, short-term and long-term memory. Journal Of Sports Sciences, 26(3), 333-344. doi:10.1080/02640410701591417

Cooper-Kahn, J. & Dietzel, L. (n.d.). What Is Executive Functioning? Retrieved February 06, 2018, from http://www.ldonline.org/article/29122/

de Paula, J. J., Malloy-Diniz, L. F., Romano-Silva, M.A. (2016). *Reliabilty of Working Memory Assessment in Neurocognitive Disorders: A Study of the Digit Span and Corsi Block-Tapping Tasks.* Retrieved from http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-44462016000300262

Donchin, E., & Coles, M. G. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences, 11*(03), 357. doi:10.1017/s0140525x00058027

Duncan-Johnson, C.C., 1981. P3 latency: A New Metric of Information Processing. Psychophysiology 18, 207–215.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of Noise Letters Upon the Identification of a Target Letter in a Nonsearch Task. *Perception & Psychophysics,16*(1), 143-149. DOI:10.3758/bf03203267

Eriksen, C. W., & Schultz, D. W. (1979). Information processing in visual search: A continuous flow conception and experimental results. *Perception & Psychophysics, 25*(4), 249-263. doi:10.3758/bf03198804

Etnier, J. L., Wideman, L., Labban, J. D., Piepmeier, A. T., Pendleton, D. M., Dvorak, K. K., & Becofsky, K. (2016). The Effects of Acute Exercise on Memory and Brain-Derived Neurotrophic Factor (BDNF). *Journal Of Sport & Exercise Psychology*, 38(4), 331-340. doi:10.1123/jsep.2015-0335

Galvan, V., Vessal, R., & Golley, M. T. (2013). The Effects of Cell Phone Conversations on the Attention and Memory of Bystanders. *Plos ONE, 8*(3), 1-10. doi:10.1371/journal.pone.0058579

Hillman, C. H., Snook, E. M., & Jerome, G. J. (2003). Acute cardiovascular exercise and executive control function. *International Journal of Psychophysiology, 48*(3), 307-314. Doi: 10.1016/s0167-8760(03)00080-1

Hsieh, S., Chang, Y., Hung, T., & Fang, C. (2016). The effects of acute resistance exercise on young and older males' working memory. *Psychology of Sport & Exercise, 22* 286-293. doi:10.1016/j.psychsport.2015.09.004

Kang, G., Jecanski, I. N., Chohan, E., Badyal, A. (2018). Adapted Digit Span Examination Sheet. Adapted from Turner, M. (2004). The Digit Memory Test. Retrieved from https://www.cpp.edu/~nalvarado/PSY335%20PPTs/Baddeley/BChap2&3.pdf

Koutsandreou, F., Wegner, M., Niemann, C., & Budde, Hm (2016). Effects of Motor versus

Cardiovascular Exercise Training on Children's Working Memory. *Medicine & Science in Sports & Exercise*, *48*(6), 1144-1152. doi:10.1249/MSS.0000000000000869

Lambourne, K., & Tomporowski, P. (2010). The effect of exercise-induced arousal on cognitive task performance: A meta-regression analysis. *Brain Research, 1341*, 12-24. doi:10.1016/j.brainres.2010.03.091

Magnie, M., Bermon, S., Martin, F., Madany-Lounis, M., Suisse, G., Muhammad, W., & Dolisi, C. (2000). P300, N400, aerobic fitness, and maximal aerobic exercise. *Psychophysiology, 37*(3), 369-377. doi:10.1111/1469-8986.3730369

McNerney, M. W. & Radvansky, G. A. (2015). Mind racing: The influence of exercise on long-term memory consolidation. *Memory, 23*(8), 1140-1151. Doi: 10.1080/09658211.2014.962545

Nakamura, Y., Nishimoto, K., Akamatu, M., Takahashi, M., Maruyama, A., (1999). The Effect of Jogging on P300 Event Related Potentials. *Electroencephalography Clinical Neurophysiology*. 39, 71–74.

Oberauer, K. (2017). What is working memory capacity? / ¿Qué es la capacidad de la memoria de trabajo?. *Estudios De Psicologia, 38*(2), 338-384. doi:10.1080/02109395.2017.1295579

Ranganath, T. S., & Josephine, P. K. (2015). Assessment of learning style preferences of medical undergraduate students: A cross-sectional study. *International Journal Of Medicine & Public Health*, *5*(2), 196-199. doi:10.4103/2230-8598.153837

Sage, M. D., Beyer, K. B., Laylor, M., Liang, C., Roy, E. A., & McIlroy, W. E. (2016). A single session of exercise as a modulator of short-term learning in healthy individuals. *Neuroscience Letters,* 62992-98. doi:10.1016/j.neulet.2016.06.064

Schwarb, H., Nail, J., & Schumacher, E. (2016). Working memory training improves visual short-term memory capacity. *Psychological Research*, *80*(1), 128-148. doi:10.1007/s00426-015-0648-y

Shu-Shih, H., Chin-Lung, F., Tsung-Min, H., & Yu-Kai, C. (2016). Acute Resistance Exercise Facilitates Attention Control in Adult Males without an Age-Moderating Effect. *Journal Of Sport & Exercise Psychology*, *38*(3), 247-254. doi:10.1123/jsep.2015-0282

Sibley, B. A., & Beilock, S. L. (2007). Exercise and Working Memory: An Individual Differences Investigation. *Journal of Sport & Exercise Psychology, 29(*6), 783-791.

Vaughn, L. M., & Baker, R. C. (2008). Do Different Pairings of Teaching Styles and Learning Styles Make a Difference? Preceptor and Resident Perceptions. *Teaching & Learning In Medicine*, *20*(3), 239-247. doi:10.1080/10401330802199559

Wang, X. & Wang, G. (2016). Effects of treadmill exercise intensity on spatial working and long-term memory in rats. *Life Sciences*. *149*(1), 96-103. Doi: 10.1016/j.lfs.2016.02.070

Wickens, C., Kramer, A., Vanasse, L., & Donchin, E. (1983). Performance of concurrent tasks: a psychophysiological analysis of the reciprocity of information-processing resources. *Science, 221*(4615), 1080-1082. doi:10.1126/science.6879207

Zach, S., & Shalom, E. (2016). The Influence of Acute Physical Activity on Working Memory. *Perceptual & Motor Skills*, *122*(2), 365-374. doi:10.1177/0031512516631066